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STUDENT HANDOUT

TRANSISTORS

Terminal Learning Objective: Given a schematic, a faulty generator set electrical system, and applicable tools and test equipment, with the aid of references, repair the generator set electrical system so that it functions properly in accordance with the appropriate equipment technical manual. (1142.01.02)

Enabling Learning Objective(s):

(1) Given a list of transistor operating characteristics, select the characteristics that apply to a NPN transistor, in accordance with FM 11-62. (1142.01.03bi)

(2) Given a list of transistor operating characteristics, select the characteristics that apply to a PNP transistor, in accordance with FM 11-62. (1142.01.03bj)

(3) Given a description of an ohmmeter being used to test a transistor junction, state whether the junction is good or bad, in accordance with FM 11-62. (1142.01.03bk)

(4) Given a list of biased transistors, select the correctly biased transistor, in accordance with FM 11-62. (1142.01.03bl)

(5) Given the formula P=Vce * Ic, the collector to emitter voltage and the collector current, select the appropriate transistor power rating, in accordance with FM 11-62. (1142.01.03bm)

(6) Given a schematic diagram of a differential amplifier and a list of circuit operating characteristics, identify the characteristics that apply to the differential amplifier in accordance with FM 11-62 (1142.01.03bn)

Outline

1. Transistor Fundamentals:

a. The first solid-state device discussed was the two-element semiconductor diode. The next device on our list is even more unique. It not only has one more element than the diode but it can amplify as well. Semiconductor devices that have three or more elements are called TRANSISTORS. The term transistor was devised from the words TRANSfer and resISTOR. This term was adopted because it best describes the operation of the transistor, the transfer of an input signal current from a low resistance circuit to a high resistance circuit. Basically, the transistor is a solid state device that amplifies by controlling the flow of current carriers through the semiconductor materials.

b. There are many different types of transistors, but their basic theory of operation is all the same. As a matter of fact, the theory we will be using to explain the operation of a transistor is the same theory used earlier with the PN-junction diode except that now, two such junctions are required to form the three elements of a transistor. The three elements of the two junction transistor are:

(1) The EMITTER, which gives off or "emits", majority current carriers (electrons or holes).

(2) The BASE, which controls the flow of majority current carriers.

(3) The COLLECTOR, which collects the majority current carriers.

2. Classification:

a. Transistors are classified as either PNP or NPN according to the arrangement of their N and P type materials. Their basic construction and chemical treatment is implied by their names, "NPN" or "PNP". That is, an NPN transistor is formed by introducing a thin region of P-type material between two regions of N-type material. On the other hand, a PNP transistor is formed by introducing a thin region of N-type material between two regions of P-type material. Transistors constructed in this manner have two PN junctions, as shown on this slide. One PN junction is between the emitter and the base; the other PN junction is between the collector and the base. The two junctions share one section of semiconductor material so that the transistor actually consists of three elements.

b. Since the majority and minority current carriers are different for N and P type materials, then it stands to reason that the internal operation of the NPN and PNP transistors will also be different. The theory of operation of the NPN and PNP transistors will be discussed separately in the next few paragraphs. Any additional information about the PN junction will be given as the theory of transistor operation is explained.

c. In order to prepare you for the forthcoming information, the two basic types of transistors along with their circuit symbols are shown in this slide. It should be noted that the two symbols are different. The horizontal line represents the base, the angular line with the arrow on it represents the emitter. The direction of the arrow on the emitter distinguishes the NPN from the PNP transistor. If the arrow points in, the transistor is a PNP (Points iN). On the other hand, if the arrow points out, the transistor is an NPN (Not Pointing iN). Another point you should keep in mind is that the arrow always points in the direction of hole flow, or from the P to N sections, whether the P section is the emitter or base. On the other hand, electron flow is always toward or against the arrow, just like in the junction diode.

4. Transistor Thoery:

a. You should recall from a previous discussion that a forward-biased PN junction is comparable to a low-resistance circuit element because it passes a high current for a given voltage. In turn, a reverse-biased PN junction is comparable to a high resistance circuit element. By using Ohm's law formula for power ($P=I^2R$) and assuming the current is held constant, you can conclude that the power developed across a high resistance is greater than that developed across a low resistance. Thus, if a crystal were to contain two PN junctions (one forward-biased and the other reverse-biased), a low power signal could be injected into the forward-biased junction to produce a high-power signal at the reverse-biased junction. In this manner, a power gain would be obtained across the crystal. This concept is the basic theory behind how the transistor amplifies. With this information fresh in our mind, let's proceed directly to the NPN transistor.

5. NPN Transistor Operation:

a. Just as in the case of the PN junction diode, the N material comprising the two end sections of N P N transistor contains a number of free electrons, while the center P section contain an excess of holes.

(1) The action at each junction between these sections is the same as that previously described for the diode; that is, depletion regions develop and the junction barrier appears. In order to use the transistor as an amplifier, each of these junctions must be modified by some external bias voltage.

(2) The first PN junction (emitter-base junction) is biased in the forward, or low resistance, direction.

(3) At the same time the second PN junction (base-collector junction) is biased in the reverse, or high-resistance, direction. A simple way to remember how to properly bias a transistor is to observe the NPN or PNP elements that make up the transistor. The letters of these elements indicate what polarity voltage to use for correct bias.

EXAMPLE: The emitter, which is the first letter in the NPN sequence, is connected to the negative side of the battery, while the base, which is the second letter (NPN), is connected to the positive side. However, since the second PN junction is required to be reverse biased for proper transistor operation, then the collector must be connected to an opposite polarity voltage (positive) than that indicated by its letter designation (NPN). The voltage on the collector must also be more positive than the base.

6. NPN Forard Bais Junction:

a. An important point to bring out at this time is the fact that the N material on one side of the forward-biased junction is more heavily doped than the P material. This results in more current being carried across the junction by the majority carrier electrons from the N material than the majority carrier holes of the P material.

b. Therefore, conduction through the forward-biased junction Is mainly by <u>majority carrier electrons</u> from the N material (emitter).

(1) With the emitter-to-base junction biased in the forward direction, electrons leave the negative terminal of the battery and enter the N material (emitter).

(2) Since electrons are majority current carriers in the N material, they pass easily through the emitter, cross over the junction, and combine with holes in the P material (base).

(3) For each electron that fills a hole in the P material, another electron will leave the P material (creating a new hole), and enter the positive terminal of the battery.

7. <u>NPN Reverse Bais Juction</u>:

a. The second PN junction (base-to-collector), or reverse-biased junction as it is called, blocks the majority current carriers from crossing the junction. However, there is a very small current that does pass through this junction.

(1) This current is called <u>minority current</u>, or <u>reverse current</u>. As you recall, this current is caused by electron-hole pairs.

(2) The minority carriers for the reverse-biased PN junction are the <u>electrons</u> in the P material and the <u>holes</u> in the N material. These minority carriers actually conduct the current for the reverse-biased junction when electrons from the P material enter the N material, and the holes from the N material enter the P material.

(3) However, the minority current electrons (as you will see later) play the most important part in the operation of the NPN transistor.

b. At this point you may wonder why the second PN junction (base-to-collector) is not forward biased like the first PN junction (emitter-to-base). If both junctions were forward biased, the electrons would have a tendency to flow from each end section of the <u>NPN</u> transistor (emitter and collector) to the center P section (base). In essence, we would have two junction diodes possessing a common base, thus eliminating any amplification and defeating the purpose of the transistor.

c. A word of caution is in order at this time. If you should mistakenly bias the second PN junction in the forward direction, the excessive current would develop enough heat to destroy the junctions, making the transistor useless. Therefore, make sure your bias voltage polarities are correct before making any electrical connections.

8. <u>NPN Junction Interactive</u>:

a. We are now ready to see what happens when we place two junctions of the NPN transistor in operation at the same time.

b. As stated earlier, the current flow in the external circuit is always due to the movement of free electrons. Therefore, electrons flow from the negative terminals of the supply batteries to the N-type emitter. This combined movement of electrons is known as emitter current ($I_{E.)}$). Since electrons are the majority carriers in the N material, they will move through the forward biased, Emitter-Base Junction, into the base region. Once the electrons are in the base, which is a P-type material, they now become minority carriers. Some of the electrons that move into the base recombine, and move out through the base lead as base current ($I_{B)}$, creating a new hole that eventually combines and returns to the base supply battery. The electrons that recombine are lost as far as the collector is concerned. Therefore, in order to make a transistor more efficient, the base region is made very thin and lightly doped. This reduces the opportunity for an electron to recombine with a hole and be lost. Thus, most of the electrons that move into the base region come under the influence of the large collector reverse bias. This bias acts as forward bias for the minority carriers, electrons, in the base and, accelerates them through the base-collector junction and into the collector region. Since the collector is made of an N-type material, the electrons that reach the collector, move easily through the N material and return to the positive collector current, (I_C). To further improve the efficiency of the transistor, the collector is made physically larger than the base for two reasons:

(1) To increase the chance of collecting carriers that diffuse to the side as well as directly across the base region.

(2) To enable the collector to handle more heat without damage

In summary, total current flow in the NPN transistor is through the emitter lead. Therefore, in terms of percentage, I_E is 100 percent. On the other hand, since the base is very thin and lightly doped, then a smaller percentage of the total current, emitter current, will flow in the base circuit than in the collector circuit. Usually no more than 2 to 5 percent of the total current is base current (I_B), while the remaining 95 to 98 percent is collector current (I_C). A very basic relationship exists between these two currents: $I_E = I_B + I_{C.}$ In simple terms this means that the emitter current is separated into base and collector current. Since the amount of current leaving the emitter is solely a function of the emitter-base bias, and because the collector receives most of this current. In conclusion, the relatively small emitter-base bias controls the relatively large emitter-to-collector current.

9. PNP Transistor Operation:

a. The PNP transistor works essentially the same way as the NPN transistor. However, since the emitter base and collector in the PNP transistor are made of material that are different from those used in the NPN transistor, different current carriers flow in the PNP unit.

(1) The majority current carriers in the PNP transistor are holes. This is in the contrast to the NPN transistor where majority current carriers are electrons. In order to support this different type of current, hole flow, the bias batteries are reversed for the PNP transistors.

(2) The procedure used earlier to properly bias the NPN transistor also applies to the PNP transistor. The first letter, P, in the PNP sequence indicates the polarity of the voltage, positive. Since the base-collector junction is always reverse-biased, then the opposite polarity voltage, Negative, must be used for the collector. Thus, the base of the PNP transistor must be negative with respect to the emitter, and the collector must be more negative than the base. Remember, just as in the case of the NPN transistor, this difference in supply voltage is necessary in order to have current flow. Hole flow in the case of the PNP transistor, is from the emitter to the collector. Although hole flow is the predominant type of current flow in the PNP transistor, hole flow only takes place within the transistor itself, while electrons flow in the external circuit. However, it is the internal hole flow that leads to electron flow, occurs in the external wires connected to the transistor.

10. PNP Forward Bais Jucntion:

a. Now let us consider what happens when the emitter-base junction, depicted here, is forward biased. With the bias setup shown, the positive terminal of the battery repels the emitter holes toward the base, while the negative terminal drives the base electrons toward the emitter. When an emitter hole and a base electron meet, they combine. For each electron that combines with a hole, another electron leaves the negative terminal of the battery, and enters the base.

b. At the same time an electron leaves the emitter, creating a new hole that enters the positive terminal of the battery. This movement of electrons into the base and out of the emitter constitute base current flow (I_B), and the path the electrons take is referred to as the emitter-base circuit.

11. PNP Reverse Bais Junction:

a. In the reverse-biased junction seen here, the negative voltage on the collector and the positive voltage on the base, block the majority current carriers from crossing the junction. However, this same negative collector voltage acts as forward bias for the minority current holes in the base, which cross the junction and enter the collector.

b. The minority current electrons in the collector also sense the forward bias, (the positive base voltage), and move into the base. The holes in the collector are filled by electrons that flow from the negative terminal of the battery.

c. At the same time the electrons leave the negative terminal of the battery, other electrons in the base break their covalent bonds and enter the positive terminal of the battery. Although there is only minority current flow in the reverse-biased junction, it is still very small due to the limited amount of minority current carriers.

12. PNP Junction Interaction:

a. The interaction between the forward and reverse-biased junctions in a PNP transistor is very similar to that in a NPN transistor, except that in the PNP transistor, the majority current carriers are holes. In the PNP transistor, shown here, the positive voltage on the emitter repels the holes toward the base. Once in the base, the holes combine with base electrons. But again, remember that the base region is made very thin to prevent recombination of holes with electrons. Therefore, well over 90 percent of the holes that enter the base become attracted to the large negative collector voltage and pass right through the base. However, for each hole and electron that combine in the base region, another electron leaves the negative terminal of the base battery, and enters the base as base current (I_B). At the same time an electron leaves the negative terminal of the battery, another electron leaves the emitter as (I_E), creating a new hole, and enters the positive terminal of B(BB). Meanwhile, in the collector circuit, electrons from the collector battery enter the collector as (I_C) and combine with the excess holes from the base. For each hole that is neutralized in the collector by an electron, another electron leaves the emitter and starts its way back to the positive terminal of the collector battery.

b. Although current flow in the external circuit of the PNP transistor is opposite in direction to that of an NPN transistor, the majority carriers always flow from the emitter to the collector. This flow of majority carriers also results in the formation of two individual current loops within each transistor. One loop is the base-current path and the other is the collector-current path. The combination of the current in both of these loops, (I_B & I_C) results in total transistor current (I_E). The most important thing to remember about the two different types of transistors is that the emitter-base voltage of the PNP transistor has the same controlling effect on the collector current as that of the NPN transistor. In simple terms, increasing the forward-bias voltage of a transistor reduces the emitter-base junction barrier. This action allows more carriers to reach the collector and travel through the external circuit. Conversely, a decrease in the forward-bias voltage reduces collector current.

13. <u>Transistor Specification</u>:

a. Transistors are available in a large variety of shapes and sizes, each with its own unique characteristics. The characteristics for each of these transistors are usually presented on SPECIFICATION SHEETS or they may be included in transistor manuals. Although many properties of a transistor could be specified on these sheets, manufacturers list only some of them. The specifications listed vary with different manufacturers, the type of transistor, and the application of the transistor. The specifications usually cover the following items.

b. A general description of the transistor includes:

(1) The kind of transistor. This covers the materials used, such as germanium or silicon, the type of transistor, NPN or PNP, and the construction of the transistor, whether alloy junction, grown, or diffused junction and so on.

(2) Some of the common applications for the transistor, such as audio amplifier, oscillator, or amplifier, and so on.

(3) General sale features, such as size and packaging (mechanical data).

c. The "Absolute Maximum Ratings" of the transistor are the direct voltage and current values, that if exceeded in operation, may result in transistor failure. Maximum ratings usually include collector-to-base voltage, emitter-to-base voltage, collector current, emitter current, and collector power dissipation. Collector power dissipation is the most important. By using the formula V_{ce} X I_c = P_d, it can be determined if the absolute maximum ratings are within circuit requirements.

d. This slide shows, the typical operating values of the transistor. These values are presented only as a guide. The values vary widely, are dependent upon operating voltages, and also upon which element is common in the circuit. The values listed may include collector-emitter voltage, collector current, input resistance, load resistance, current-transfer ratio, and collector cutoff current, which is leakage current from collector to base when no emitter current is applied. Transistor characteristic curves may also be included in this section. A transistor characteristics curve is a graph plotting the relationship between currents and voltages in a circuit. More than one curve on a graph is called a "family of curves".

14. <u>Transistor Identification</u>:

a. Transistors can be identified by a Joint Army-Navy (JAN) designation printed directly on the case of the transistor. The marking scheme explained earlier for diodes is also used for transistors. The first number indicates the number of junctions. The letter "N" following the first number tells us that the component is a semiconductor. And, the 2 or 3 digit number following the N is the manufacturers identification number. If the last number is followed by a letter, it indicates a later, improved version of the device. for example, a semiconductor designated as type 2N130A signifies a three element transistor of semiconductor material that is an improved version of type 130:

2	N	130	A
Number of Junctions (transistors)	Semiconductor Material	Identification Number	First Modification

b. You may also find other markings on transistors which do not relate to the JAN markings system. These markings are manufacturer's identifications and may not conform to a standardized system. If in doubt, always replace a transistor with one having identical markings. To ensure that an identical replacement or a correct substitute is used, consult an equipment or transistor manual for specifications on the transistor.

15. <u>Transistor Maintenance</u>:

a. Transistors are very rugged and are expected to be relatively trouble free. Encapsulation and conformed coating techniques now in use, promise extremely long life expectancies. In theory, a transistor should last indefinitely. However, transistors are subjected to current overloads, the junctions may be damaged or even destroyed. In addition, the application of excessively high operating voltages can damage or destroy the junction through arc over or excessive reverse currents. One of the greatest dangers to transistors is heat, which will cause excessive current flow and eventual destruction of the transistors.

b. In order to determine if a transistor is good or bad, you can check it with an ohmmeter or a transistor tester. In many cases, you can substitute a transistor known to be good for one that is questionable and thus determine the condition of a suspected transistor. This method of testing is highly accurate and some times the quickest, but is should be used only after you have determined no other circuit defects that might damage the replacement transistor. If more than one defective transistor is found in the equipment where the trouble has been localized, this testing method becomes cumbersome, as several transistors may have to be replaced before the trouble is corrected. To determine which stages failed and which transistors are still good, all the removed transistors must be tested. This can be done using a standard ohmmeter, a transistor tester, or by observing whether the equipment operates properly as each of the removed transistors are reinstated into the equipment. A word of caution, indiscriminate substitution of transistors in critical circuits should be avoided.

c. When transistors are soldered into equipment, substitution is not practical; it is generally desirable to test these transistors in their circuits.

6. <u>Precaution</u>:

a. Transistors, although generally rugged, are susceptible to damage by electrical overloads, heat, humidity, and radiation. Damage of this nature often occurs during transistor servicing by applying the incorrect polarity voltage to the collector circuit or excessive voltage to the input circuits. Careless soldering techniques that overheat the transistor have also been known to cause considerable damage. One of the most frequent causes of damage to a transistor is the electrostatic discharge from the human body when the device is handled. You may avoid such damage before starting repairs by discharging body static electricity to the chassis of the unit containing the transistors. To do this you just touch the chassis.

b. To prevent transistor damage and avoid electrical shock, you should observe the following precaution when you are working with transistorized equipment:

(1) <u>Test equipment and soldering irons</u> should be checked to make certain that there is no leakage current from the power source. If leakage current is detected, isolation transformers should be used.

(2) Always connect a ground between test equipment and the circuit before attempting to inject or monitor a signal.

(3) Ensure test voltages do not exceed maximum allowable voltage for the circuit components and transistors. Also, never connect test equipment outputs directly to a transistor circuit.

(4) Ohmmeter ranges which require a current of more than one milliampere in the test circuit, should not be used for testing transistors.

(5) Battery eliminators should not be used to furnish power for transistor equipment because they have poor voltage regulation and possibly high-ripple voltage.

(6) The heat applied to a transistor, when soldered connections are required, should be kept to a minimum by using a low-wattage soldering iron and heat shunts, such as long nose pliers, on the transistor leads.

(7) When it becomes necessary to replace transistors, never pry transistors to loosen them from the printed circuit boards.

(8) All circuits should be checked for defects before replacing a transistor.

(9) The power must be removed from the equipment before replacing a transistor.

(10) Using conventional test probes on equipment with closely spaced parts, often causes accidental shorts between adjacent terminals. These shorts may ruin a transistor. To prevent these shorts, the probes can be covered with insulation, except for a very short portion of the tips.

17. Lead Identificatioin:

a. Transistor lead identification plays an important part in transistor maintenance; because, before a transistor can be tested or replaced, its leads or terminals must be identified. Since there is no standard method of identifying transistor leads, it is quite possible to mistake one lead for another. Therefore, you should pay close attention to how the transistor is mounted, particularly to those that are soldered on, so that you do not make a mistake when you are installing the new transistor. When you are testing or replacing a transistor, if you have any doubts about which lead is which, consult the equipment manual or a transistor manual that shows the specifications for the transistor being used. There are, however, some typical lead identification schemes that will be very helpful in transistor troubleshooting.

b. These schemes are shown here, in case of the oval shaped transistors shown in view "A", the collector lead is identified by a wide space between it and the lead. When the leads are evenly spaced and in line, is the emitter lead. When the leads are evenly spaced and in line, as shown in view "B" a colored dot, usually red, indicates the collector. If the transistor is round, as in view "C", a red line indicates the collector, and the emitter lead is the short lead. In view "D", the leads are in a triangular arrangement which is offset from the center of the transistor. The lead opposite the blank quadrant in this scheme is the base lead. When viewed from the bottom, the collector is the first lead clockwise from the base. The leads in view "C" are arranged in the same manner as those in view "D" except that a tap is used to identify the leads. When viewed from the bottom in a clockwise direction, the first lead following that tab is the emitter, followed by the base and collector.

c. In a conventional power transistor as shown in views "F" and "G", the collector lead is usually connected to the mounting base. For further identification, the base lead in view "F" is covered with green sleeving. While the leads in view "G" are identified by viewing the transistor from the bottom in a clockwise direction, with mounting holes occupying 3 o'clock and 9 o'clock, the emitter lead will be at either 5 o'clock or 11 o'clock. The other lead is the base lead.

18. Transistor Testing:

a. There are several different ways of testing transistors. They can be tested while in the circuit, by the substitution method previously mentioned, or with an ohm meter or transistor tester.

b. Transistor testers are nothing more than the solid-state equivalent of the electron-tube testers, although they do not operate on the same principle. With most transistor testers it is possible to test the transistor in or out of the circuit.

c. Since it is impractical to cover all the transistor testers, which come with operation manuals, we will move on to what we use more frequently, the ohmmeter.

19. Testing Transistor Using An Ohmmeter:

a. There are four basic test required for transistors in practical troubleshooting: gain, leakage, breakdown, and switching time. For maintenance and repair however, it is usually not necessary to check all of these parameters. Two or three of these parameter checks is usual sufficient to determine if a transistor needs replacement. Two of the most important parameters used for testing are gain and leakage. The following paragraphs will give you a good idea of how to use the ohmmeter to check for transistor gain and leakage.

b. Transistor Gain Test - A basic transistor gain test can be made using an ohmmeter and a simple test circuit. The test circuit can be made with just a couple of resistors and a switch, as shown here. The principle behind the test lies in the fact that little or no current will flow in a transistor between emitter and collector until the emitter-base junction is forward biased. The only precaution you should observe is with the ohmmeter. Any internal battery may be used in the meter, provided it does not exceed the maximum collector emitter breakdown voltage.

(1) With the switch in the open position as shown, no voltage is applied to the PNP transistor's base, and the emitter-base junction is not forward biased. Therefore, the ohmmeter should read a high resistance as indicated on the meter. When the switch is closed, the emitter-base junction is forward biased by the voltage across R1 and R2. Current now flows in the emitter-collector circuit which causes a lower resistance reading on the ohmmeter. A 10 to 1 resistance ratio in this test between meter readings indicates a normal gain for an audio-frequency transistor.

(2) To test an NPN transistor using this circuit, simply reverse the ohmmeter leads and carry out the procedure described earlier.

c. Transistor Leakage Test - An ohmmeter can be used to test a transistor for leakage, an undesirable flow of current, by measuring the base-emitter, base-collector, and collector-emitter forward and reverse resistance.

(1) For simplicity, consider the transistor under test in each view here, as two diodes connected back to back. Therefore, each diode will have a low forward resistance and a high-reverse resistance, except for between the emitter and collector which will always have a high resistance. By measuring these resistances with an ohmmeter as shown, you can determine if the transistor is leaking current through the junctions. When making these measurements avoid using the RX1 scale on the meter or a meter with a high internal battery voltage. Either of these conditions can damage a low-power transistor.

(2) Now consider the possible transistor problems that could exist if the indicated readings in this diagram are not obtained. Here is a list of these problems.

(3) By now you should recognize that the transistor used in slide #13 is a PNP transistor. If you wish to test an NPN transistor for leakage, the procedure is identical to that used for testing the PNP, except the readings obtained are reversed.

(4) When testing transistors, PNP or NPN, you should remember that the actual resistance values depend on the ohmmeter scale and the battery voltage. Typical forward and reverse resistances are insignificant. The best indicator for showing whether a transistor is bad or good is the ratio of forward-to- reverse resistance. If the transistor you are testing shows a ration of at least 80 to 1, it is probably good. Many transistors show ratios of 100 to 1 or greater.

20. Differential Amplifier (DIF AMP):

a. The Differential Amplifier functions are as follows:

(1) We will assume that CRI is a 4 volt zener diode. It will hold a constant +4 volts with respect to ground, on the base of Q2. This will turn Q2 on and allow current to flow from ground, through R3, in and out of Q2, through R4, to positive. The current flow through R3 will create a 3.2 volt drop across it, negative at the

bottom and positive at the top. This will make the base of Q2 about .8 volt positive with respect to the emitter and cause forward bias of the emitter-base junction and Q2 will still be on. We will also assume that S.0.D. (Some Other Device) has a 3 volt drop across it. This will put a +3 volts on the base of Q1, while its emitter has +3.2 volts. This will give Ql a -.2 volt reverse bias and Ql will be off. Thus, Ql is off and Q2 is on.

(2) Now, we will assume that S.0.D. has a resistance change and its voltage drop will rise to 5 volts. This will forward bias Ql and turn it on. This will cause an increase in current flow through R3 and raise its voltage drop from 3.2 to 4 volts. Ql now has a 1 volt forward bias and Q2 has an even, or zero bias and it will be off. Thus, Ql is on and Q2 is off.

b. The Dif Amp is used to sense a small changes in potential and amplify it. Q2 is the stable side because CRI and Ql is the sensing side. The sensing side will react to any change and cause Q2 to do the opposite. The sensing side can receive its potential from any source.

REFERENCES:

1. FM 11-62